Measurement and Minimization of Wing Tilt in Laterally Overgrown GaN on a SiO_2 Mask

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Numerous groups have demonstrated the effectiveness of the lateral epitaxial overgrowth (LEO) technique in significantly lowering dislocation densities in heteroepitaxial GaN films.[1-4] Reductions in dislocation density have yielded direct improvements in device performance, most notably in GaN-based lasers,[5-7] LEDs,[8,9] and UV photodetectors.[10] Despite these LEO-based device performance improvements, some difficulties remain in controlling the structural quality of the overgrown material, particularly for fully coalesced films. For the case of LEO from $<1\bar{1}00>$ or $<11\bar{2}0>$-oriented stripes, it has been observed that crystal planes in the 'wings' (overgrown GaN) exhibit tilts away from those in the 'window' (seed) regions in a direction perpendicular to the stripes.[2,3,11] Coalescence of wings from neighboring stripes may then generate additional extended defects.[2,3]

Although the exact origin(s) of wing tilt is(are) unknown at the current time, it is obviously desirable to minimize or eliminate wing tilt altogether. Wing tilt is readily measurable by performing an x-ray diffraction measurement such as an ω rocking curve, with the scattering plane oriented perpendicular to the stripe direction. In this presentation, we discuss the use of XRD omega scans in conjunction with scanning electron microscope (SEM) measurements to derive the dependence of wing tilt on stripe morphology. We empircally correlate wing tilt with the ratio of wing width (w) to height (h) as measured in cross section, which is directly dependent on growth conditions (*e.g.*, V/III ratio, temperature) and 'fill factor' (the ratio of open width to pattern period). An example of this is shown in Fig. 1. Since wing tilt increases monotonically as w/h increases, wing tilt values lower than 0.1° have been achieved by carefully controlling the stripe cross-sectional aspect ratio.

In addition to performing numerous XRD measurements at room temperature, we have also accomplished successful *in situ*, real-time x-ray diffraction measurements of wing tilt **during** lateral overgrowth. Experiments were conducted in a vertical two-flow MOCVD chamber mounted on a 'z-axis' surface diffractometer, located on the BESSRC undulator beamline 12-ID-D at the Advanced Photon Source.[12,13] LEO was performed on SiO_2-patterned GaN/sapphire seed layers using $<1\bar{1}00>$-oriented lines of nominal 5µm opening and 20µm period. During LEO, line scans through the $10\bar{1}3$ point in reciprocal space were repeatedly made, such that the evolution of wing tilt was observed. As shown in Fig. 2, wing tilt (visible as peaks on both sides of the GaN bulk peak) emerged early (< 300s) in the growth and rapidly reached a value of ~1°, with an increase to ~1.19° after 3600s of growth. Upon cooldown to room temperature, the tilt increased slightly to only ~1.36°, which indicated that thermally-induced stresses at the wing-mask interface are not dominant in determining tilt magnitude. These x-ray diffraction measurements as well as complementary SEM and TEM results will be discussed, with an emphasis on approaching an explanation for the origin(s) of wing tilt.

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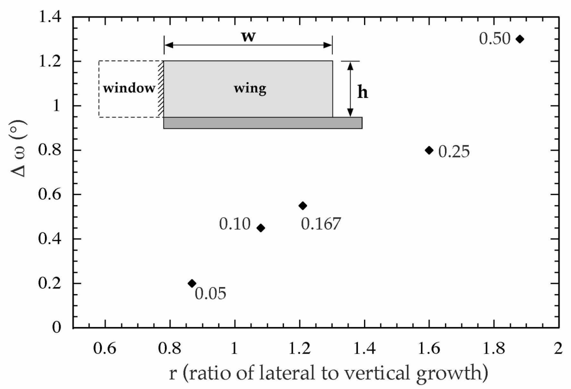

Figure 1. Wing tilt (Δω) vs. wing aspect ratio in cross section (r = w/h). Stripe pattern fill-factors are noted next to each point.

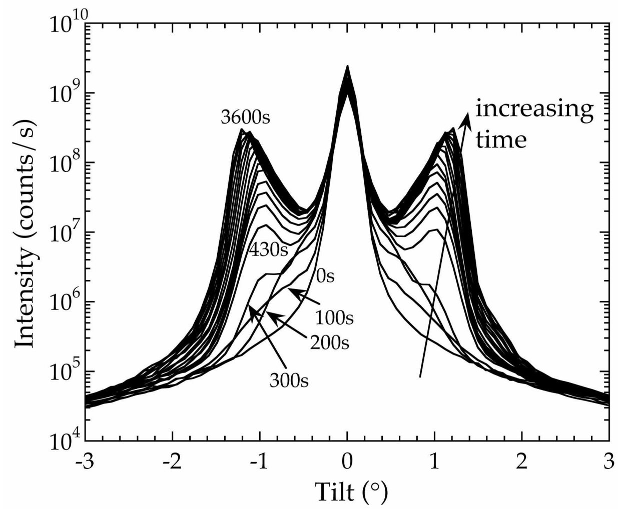

Figure 2. Intensity vs. wing tilt, scanned repeatedly during LEO growth, for a total of 3600s. Early scans are labelled with time at beginning of scan, in seconds.

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